CIRCUIT BREAKER TRIP UNIT EMPLOYING A RESET OVERTRAVEL COMPENSATING ROTARY TRIP LEVER

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to commonly assigned, concurrently filed:

United States Patent Application Serial No. __/_________, filed _______ ____, 2003, entitled "Circuit Breaker Trip Unit Employing A Rotary Plunger" (Attorney Docket No. 02-EDP-353); and

United States Patent Application Serial No. __/_________, filed _______ ____, 2003, entitled "Circuit Breaker Trip Unit Including a Plunger Resetting a Trip Actuator Mechanism and a Trip Bar" (Attorney Docket No. 02-EDP-356).

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to electrical switching apparatus and, more particularly, to circuit breakers employing a trip unit. The invention also relates to circuit breaker trip units.

Background Information

Circuit breakers and circuit breaker trip units are well known in the art. See, for example, U.S. Patent Nos. 5,910,760; and 6,144,271.

Resetting of a circuit breaker (*e.g.*, through the operating handle and operating mechanism thereof) is accomplished in a manner well known in the art and is described and shown, for example, in Patent 5,910,760.

As disclosed in Patent 6,144,271, a linear plunger of the trip unit is employed to trip open the associated circuit breaker frame whenever the linear plunger is extended from the trip unit. Actuation of primary and secondary frame latches occurs exclusively by way of the extended and resetable trip unit linear plunger, which is, otherwise, normally contained entirely within the trip unit. The secondary frame latch is in disposition to be struck by an abutment surface of the extended linear plunger. In response to a reset operation, the trip unit is also reset whenever the secondary frame latch drives the extended linear plunger in the opposite direction against its plunger spring and into the trip unit.

When a design is dependent upon ensuring that a component travels a required distance, excess travel is designed into the system, called overtravel. Overtravel usually involves a component suspended by springs, in order to allow movement when rotating or translating parts interfere. Such springs require special treatment in the design of their supporting parts and, also, add to manufacturing costs (*e.g.*, the labor cost to install the springs).

There is a need for an improved circuit breaker employing a trip unit. There is also a need for an improved circuit breaker trip unit.

SUMMARY OF THE INVENTION

These needs and others are satisfied by the present invention which replaces springs and employs elastic properties of molded material of a rotary trip lever arm.

As an aspect of the invention, a trip unit comprises: a housing; a plunger mounted with respect to the housing, the plunger having a first position, a second position, a third position, a first portion and a second portion, the first portion of the plunger being outside of the housing in the second position, the second portion of the plunger being inside of the housing in the third position; means for latching the plunger in the first position and for releasing the plunger from the first position to the second position; means for biasing the plunger to the second position; a rotary trip lever pivotally mounted with respect to the housing, the rotary trip lever including an elastic arm, the second portion of the plunger engaging the elastic arm in the third position; and a trip actuator including a member having a first position, a second position and a third position, which resets the trip actuator, the first position of the member of the trip actuator corresponding to the first position of the plunger, the second position of the member of the trip actuator engaging and rotating the rotary trip lever in a first rotational direction, in order to engage the means for latching and release the plunger from the first position, the rotary trip lever rotating in an opposite second rotational direction in response to the third position of the plunger and engaging the member of the trip actuator, in order to move the member to the third position thereof, the elastic arm of the rotary trip lever flexing after the member

reaches about the third position thereof, in order to accommodate any overtravel of the plunger.

The plunger may include a latch surface. The means for latching the plunger may be a trip bar including a first tab and a second tab, which engages the latch surface. The rotary trip lever may include a surface, which engages the first tab of the trip bar, in order to rotate the trip bar and disengage the second tab from the latch surface of the plunger, in order to release the plunger from the first position thereof.

The elastic arm of the rotary trip lever may be made of a molded material, which flexes in response to the overtravel of the plunger beyond the third position thereof.

The rotary trip lever may be pivotally mounted on a first axis. The means for latching the plunger may be a trip bar, which is pivotally mounted on a second axis, the second axis being normal to the first axis.

The means for latching the plunger may be a trip bar pivotally mounted within the housing, the trip bar including a tab. The trip actuator further may include a linear plunger engaging the rotary trip lever, in order to rotate the rotary trip lever to engage the tab of the trip bar.

As another aspect of the invention, a trip unit comprises: a housing; a plunger mounted with respect to the housing, the plunger having a first position, a second position, a third position, a first portion and a second portion, the first portion of the plunger being outside of the housing in the second position, the second portion of the plunger being inside of the housing in the third position; a trip bar pivotally mounted with respect to the housing, the trip bar latching the plunger in the first position and releasing the plunger from the first position to the second position; a spring mechanism biasing the plunger to the second position; a rotary trip lever pivotally mounted with respect to the housing, the rotary trip lever including an elastic arm, the second portion of the plunger engaging the elastic arm in the third position; and a trip actuator including a member having a first position, a second position and a third position, which resets the trip actuator, the first position of the member of the trip actuator corresponding to the first position of the plunger, the second position of

the member of the trip actuator engaging and rotating the rotary trip lever in a first rotational direction, in order to engage the trip bar and release the plunger from the first position, the rotary trip lever rotating in a second rotational direction in response to the third position of the plunger and engaging the member of the trip actuator, in order to move the member to the third position thereof, the elastic arm of the rotary trip lever flexing after the member reaches the third position thereof, in order to accommodate any overtravel of the plunger beyond the third position thereof.

The member of the trip actuator may be a linear plunger, which engages and pivots the rotary trip lever, in order to engage and pivot the trip bar.

As another aspect of the invention, a circuit breaker comprises: a circuit breaker frame comprising: a housing, a line terminal, a load end terminal, separable contacts electrically connected between the line terminal and the load end terminal, an operating mechanism moving the separable contacts between a closed position and an open position, and a latch mechanism latching the operating mechanism to provide the closed position of the separable contacts and releasing the operating mechanism to provide the open position of the separable contacts; and a trip unit comprising: a housing, a line end terminal electrically connected to the load end terminal of the circuit breaker frame, a plunger mounted with respect to the housing, the plunger having a first position, a second position, a third position, a first portion and a second portion, the first portion of the plunger being outside of the housing in the second position, the second portion of the plunger being inside of the housing in the third position; a trip bar pivotally mounted with respect to the housing, the trip bar latching the plunger in the first position and releasing the plunger from the first position to the second position; a spring mechanism biasing the plunger to the second position; a rotary trip lever pivotally mounted with respect to the housing, the rotary trip lever including an elastic arm, the second portion of the plunger engaging the elastic arm in the third position; and a trip actuator including a member having a first position, a second position and a third position, which resets the trip actuator, the first position of the member of the trip actuator corresponding to the first position of the plunger, the second position of the member of the trip actuator engaging and rotating the rotary trip lever in a first rotational direction, in order to engage the trip bar and

release the plunger from the first position, the rotary trip lever rotating in a second rotational direction in response to the third position of the plunger and engaging the member of the trip actuator, in order to move the member to the third position thereof, the elastic arm of the rotary trip lever flexing after the member reaches the third position thereof, in order to accommodate any overtravel of the plunger beyond the third position thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the invention can be gained from the following description of the preferred embodiments when read in conjunction with the accompanying drawings in which:

Figure 1 is a front isometric view of a trip unit in accordance with the present invention.

Figure 2 is a rear isometric view of the trip unit of Figure 1.

Figure 3 is an exploded rear isometric view of the base and attachment button of Figure 2 along with a spring therefor.

Figure 4 is an exploded front isometric view of the base and rotary plunger of Figure 2 along with the spring bias mechanism therefor.

Figure 5 is a front isometric view of the assembly of Figure 4 with the trip bar, trip bar pivot member and trip bar spring being exploded from the base to show the assembly thereof.

Figure 6 is a front isometric view of the assembly of Figure 5 with the rotary trip lever and trip lever pivot member being exploded from the base to show the assembly thereof.

Figure 7 is a front isometric view of the assembly of Figure 6 with two printed circuit boards (PCBs) being exploded from the base to show the assembly thereof.

Figure 8 is a front isometric view of the assembly of Figure 7 with the trip actuator being exploded from the base to show the assembly thereof.

Figure 9 is a front isometric view of the assembly of Figure 8 including three current transformer assemblies with one of such current transformer assemblies being exploded from the base to show the assembly thereof.

Figure 10 is an exploded rear isometric view of the assembly of the cover on the assembled base of Figure 9 along with the earth leakage button and spring therefor.

Figure 11 is an exploded isometric view of the trip actuator of Figure 8.

Figures 12-14 are exploded isometric views showing the assembly of the trip actuator of Figure 11.

Figure 15 is an isometric view of the rotary plunger of Figure 2.

Figure 16 is an isometric view of the trip bar of Figure 5.

Figure 17 is an isometric view of the rotary trip lever of Figure 6.

Figures 18, 19A-19B and 20 are isometric views of the trip actuator, rotary trip lever, trip bar, and rotary plunger and spring mechanism in the latched or on position, in the reset or overtravel position, and in the tripped position, respectively.

Figure 21 is an isometric view of a circuit breaker including the trip unit of Figure 1.

Figure 22 is a plan view of the rotary plunger of Figure 15.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figures 1 and 2, a trip unit 2 is shown. The trip unit 2 includes a molded housing 4 having a base 6, a cover 8 and a top portion 10. A pair of screws 12 secures the cover 8 to the base 6. Disposed from the base 6 are three-phase line end terminals 14,16,18. The cover 8 includes corresponding load end terminals 20,22,24, respectively.

The base 6 includes a surface 26 (as shown in Figure 2), which is disposed adjacent to a circuit breaker frame 28 as shown in Figure 21. The trip unit 2 is advantageously adapted for engagement within and disengagement from the circuit breaker frame 28. The base surface 26 includes an opening 30 for a plunger, such as a rotary plunger 32 (as best shown in Figure 15), and an opening 34 for an attachment button 36 (as best shown in Figure 3). As discussed below in connection with Figures 4 and 18-20, the rotary plunger 32 is pivotally mounted with respect to the housing 4 and includes a first or on position (Figure 18), a second or tripped position (Figure 20)

and a third or reset position (Figures 1 and 19A-19B). The on position is substantially flush with the base surface 26, the tripped position is extended from the surface 26, and the reset position is pivoted within the opening 30 and recessed behind the surface 26. The cover 8 includes an opening 38 for receiving an earth leakage button 40 (as best shown in Figure 10).

Referring to Figures 3 and 5, the attachment button 36 is biased away from the surface 26 of the base 6 by a spring 42. The attachment button 36 includes a pair of legs 44 and a plunger 46 (shown in Figure 5). The legs 44 have opposing feet 48, which extend in opposite directions (up and down with respect to Figure 3), and which protrude through and are captured by openings 50 in the base 6 of Figure 5. The attachment button plunger 46 protrudes through an opening 52 of the base 6. The spring 42 is disposed between the button legs 44 and engages a surface (not shown) of the base 6 between the openings 50.

Referring now to Figures 4 and 15, Figure 4 shows the assembly of a spring bias mechanism 54 and the rotary plunger 32 (as best shown in Figure 15) at the opening 30 of the base 6. The rotary plunger 32 includes a pair of pivot posts 56, which pivotally mount the rotary plunger at a corresponding pair of pivot recesses 58 proximate the opening 30 in the housing base 6.

The spring mechanism 54 includes two bar members 60,62 and two springs 64,66. The first bar member 60 pivotally engages the rotary plunger 32 at an opening 68, the position of which is offset from the pivot posts 56 of the rotary plunger. The second bar member 62, in turn, engages a pivot recess 69 in the housing base 6 at a position offset from the pivot recesses 58 and at the opposite end of the opening 30. As shown in Figure 4, the two springs 64,66 suitably engage the opposite ends of the two bar members 60,62. For example, as best shown with the first bar member 60 and the first spring 64, the ends of the springs 64,66 have loops 70, which are captured by recesses 72 in the corresponding ends of the bar members 60,62. The springs 64,66, thus, bias the rotary plunger 32, in order that the two bar members 60,62 are in about the same plane, which is parallel to the base surface 26 of Figure 3, when the rotary plunger is in the extended or tripped position of Figure 20. This causes a portion 74 (as best shown in phantom line drawing in Figure 22) of the rotary

plunger 32 to be biased outside of the base 6 in that tripped position. Although two springs 64,66 are shown, the invention is applicable to spring mechanisms employing one (not shown) or more springs, which suitably bias a rotary plunger.

Referring to Figure 5, the assembly from Figure 4 of the base 6, the spring mechanism 54 and the rotary plunger 32 is shown, with the rotary plunger being held in the on position of Figure 18 by a trip bar 76 (as best shown in Figure 16) as will be explained below. The trip bar 76 is shown exploded for ease of illustration, although it will be appreciated that the trip bar holds the rotary plunger 32 in its on position. A trip bar pivot member 78 passes through a longitudinal opening 80 in the trip bar 76. A trip bar spring 82 rests in an opening 84 of the housing base 6. A first end 85 of the pivot member 78 rests in a first pivot point 86, and an opposite second end 87 of the member 78 rests in a second pivot point 88 of the base 6. The pivot member 78 preferably includes a portion 90 with a shoulder 91, which engages a portion 92 of the trip bar 76 where the opening 80 narrows. This precludes the member 78 from passing all the way through the longitudinal opening 80 (toward the top right of Figure 5). The trip bar 76 is, thus, pivotally mounted with respect to and within the housing 4 and functions, as will be discussed in greater detail below, to latch the rotary plunger 32 in the on position (Figure 18), to release the rotary plunger 32 from such on position to the tripped position (Figure 20), and to cooperate with the rotary plunger 32 to re-latch it in the on position after the reset position (Figures 19A-19B).

The example trip bar 76 includes: (1) a tab 94 for the plunger 46 of the attachment button 36 of Figures 3 and 5; (2) a tab 96 for a plunger 97 of the earth leakage button 40 of Figure 10; (3) a tab 98 for the bias spring 82; (4) a tab 100 for a rotary trip lever 101 (Figure 6); and (5) a latch surface 102 for a corresponding latch surface 104 (as best shown in Figure 22) of the rotary plunger 32.

Whenever the attachment button 36 (Figure 3) is depressed into the opening 34 of the surface 26 of the base 6 by a shunt (or remote) trip attachment (not shown) or by an under voltage release attachment (not shown), the button plunger 46 (Figure 5) engages the tab 94 on the trip bar 76 and rotates the trip bar clockwise (with respect to Figure 5, as viewed from the bottom left, and Figure 18). Similarly,

whenever a ground fault (*e.g.*, equipment protection) bolt on unit (not shown) engages the earth leakage button 40 (Figure 10) and depresses the same into the opening 38 of the cover 8, the button plunger 97 engages the trip bar tab 96 to also rotate the trip bar 76 in the same clockwise direction (with respect to Figures 5 and 18). The spring 82, which rests in the base opening 84, biases the trip bar 76 in the opposite rotational direction (*e.g.*, counter-clockwise with respect to Figures 5 and 18). The spring 82 engages the housing base 6 and the tab 98, in order to bias that tab and, thus, the trip bar 76 with respect to the housing 12, in order that the trip bar latch surface 102 engages the corresponding internal latch surface 104 of the rotary plunger 32 (as best shown in the on position of Figure 18). The spring 82, thus, biases the trip bar 76 to a non-actuated or on position, which holds the rotary plunger 32 and, hence, prevents the spring mechanism 54 from rotating the rotary plunger 32 to the tripped position of Figure 20. Hence, the spring 82 biases the tab 98 and the trip bar 76 to resist rotation caused by the buttons 36,40, and the trip bar latch surface 102 engages the rotary plunger latch surface 104, in order to latch the rotary plunger 32 in the on position (Figure 18). However, when the trip bar 76 is rotated (*e.g.*, by one of the buttons 36,40), the latch surface 102 moves to the right in Figure 18 and releases the latch surface 104 of the rotary plunger 32. This releases the rotary plunger 32, which is biased by the spring mechanism 54, to the tripped position (Figure 20).

A further trip operation is provided through the trip bar tab 100. The rotary trip lever 101 (Figure 6) includes a surface 106, which engages the tab 100, in order to rotate the trip bar 76 clockwise (with respect to Figures 5 and 18) and, thus, release the latch surface 102 from the rotary plunger latch surface 104, in order to release the rotary plunger from the on position (Figure 18) to the tripped position (Figure 20), as was discussed above.

Figure 6 shows the assembly from Figure 5 of the base 6, the spring mechanism 54, the rotary plunger 32, the trip bar 76 and the trip bar pivot member 78. The rotary trip lever 101 (as best shown in Figure 17) and a trip lever pivot member 108 are exploded from the base 6 for ease of illustration. The pivot member 108 passes through an opening 110 in the trip lever 101. A first end 111 of the pivot member 108 rests in a first pivot point 112, and an opposite second end 113 of the

pivot member 108 rests in a second pivot point 114 of the base 6, thereby pivotally mounting the rotary trip lever 101 with respect to the housing base 6 on an axis, which is normal to the pivot axis of the trip bar 76.

The rotary trip lever 101 includes three operating surfaces 116, 106 and 118. The first surface 116 is for engagement by a plunger 120 of a trip actuator, such as a flux shunt trip actuator 122 (Figure 8) or solenoid, which causes the rotary trip lever 101 to rotate counter-clockwise (as viewed from the bottom right of Figure 6). In turn, the second surface 106, as was discussed above, engages the tab 100 of the trip bar 76, thereby causing it to rotate clockwise (as viewed from the bottom left of Figure 6). The trip lever 101 is preferably made of a molded material. The third surface 118 is disposed on the end of an elastic arm 121, which extends from the body 123 of the trip lever 101.

In response to a force 124, which will be described, below, from a portion, such as surface 125, of the rotary plunger 32, the rotary trip lever 101 rotates in a clockwise direction (as viewed from the bottom right of Figure 6). This causes the first surface 116 of the trip lever 101 to engage the trip actuator plunger 120, in order to reset the trip actuator 122 in a manner to be described, below. In response to counter-clockwise (as viewed from the bottom left of Figure 6) overtravel of the rotary plunger 32 beyond the reset position (Figures 19A-19B) thereof, the elastic arm 121 of the rotary trip lever 101 advantageously flexes (upward with respect to Figure 6), after the trip actuator plunger 120 has been fully reset and, thus, resists further rotation of the rotary trip lever 101 by applying a force to its surface 116. Hence, the elastic arm 121 advantageously accommodates any overtravel of the rotary plunger 32 beyond its reset position, which might be caused, for example, by manufacturing or other tolerances in the circuit breaker frame 28 of Figure 21.

Referring to Figure 7, the assembly from Figure 6 includes the base 6, the spring mechanism 54, the rotary plunger 32, the trip bar 76, the trip bar pivot member 78, the rotary trip lever 101 and the trip lever pivot member 108. Exploded from the base 6 for ease of illustration is a trip circuit 126 including two printed circuit boards (PCBs) 128,130, which are interconnected by suitable electrical connectors (not shown). The first PCB 128 includes a trip actuator connector 132

disposed on one side 134. The opposite side 136 includes a pair of LED indicators 138 (only one is shown), a plurality of manual controls 140 (*e.g.*, potentiometers; rotary selectors; switches), and an interface connector 142 to a serial communication bus (not shown). The second PCB 130 includes three connectors 144,146,148 for receiving signals from three corresponding current transformers (CTs) 150,152,154 (Figure 9). The sides 155,157 of the base 6 include slots 156,158 to receive the sides of the first PCB 128, which preferably includes a rectangular cut-out portion 159 (as partially shown in Figure 10) to accommodate the rotary plunger 32 and the portion of the trip bar 76 at the latching surface 102 (Figure 5).

The invention is applicable to a wide range of analog and/or digital and/or processor-based trip circuits, such as an electronic trip circuit, which is known to those skilled in the art. Examples of electronic trip circuits are disclosed in U.S. Patent Nos. 5,428,495; and 6,167,329, which are incorporated by reference herein.

Figure 8 shows the assembly from Figure 7 including the base 6, the trip circuit 126, the rotary trip lever 101, and the trip lever pivot member 108, with the trip actuator 122 being exploded from the base for ease of illustration. The trip actuator 122 includes a set of wires 160 terminated by a connector 162, which mates with the connector 132 of the PCB 128 of the trip circuit 126 as shown in Figure 9. The trip actuator 122 rests in a recess 164 in the base 6, which provides a pair of V-shaped supports 166 (only one support 166 is shown) for the opposite ends of the trip actuator. When the trip actuator 122 is energized by the trip circuit 126 through the connectors 132,162 and the wires 160, the linear plunger 120 is in an actuated or extended state (shown in phantom line drawing). The extended linear plunger 120 engages the trip lever surface 116 (Figure 17) and rotates the rotary trip lever 101 counter-clockwise (with respect to the bottom right of Figure 8). In turn, as was discussed above in connection with Figure 6, the trip lever surface 106 engages the trip bar tab 100, which rotates the trip bar 76 and disengages the trip bar latch surface 102 from the rotary plunger latch surface 104, in order to release the rotary plunger 32 from the on position (Figure 18) and trip open the operating mechanism 167 of the attached circuit breaker frame 28 of Figure 21. The plunger 120 and the rotary trip lever 101, thus, cooperate to engage and pivot the trip bar 76.

The trip unit 2 includes a latching mechanism 168, which is formed from the combination of the trip bar 76 and the spring 82 of Figure 5, and a trip actuator mechanism 170, which is formed from the trip actuator 122 having the plunger 120 and a trip member, such as the rotary trip lever 101. The latching mechanism 168 functions to latch the rotary plunger 32 of Figure 5 in the on position (Figure 18) in which a rotary plunger surface 172 (Figures 2 and 22) is about flush with the surface 26 of the trip unit housing 4 (Figure 2, which shows the reset position of Figures 19A-19B). The latching mechanism 168 also functions to releases the rotary plunger 32 from the on position to the tripped position (Figure 20), and to re-latch the rotary plunger 32 in the on position by employing the reset position (Figures 19A-19B) thereof.

Referring to Figure 9, the assembly from Figure 8 includes the base 6, the trip circuit 126, the latching mechanism 168 having the trip actuator 122, two current transformer assemblies 174,176, and a third current transformer assembly 178, which is exploded from the base for ease of illustration. The current transformer assemblies 174,176,178 include the current transformers 150,152,154, respectively. These assemblies also include, as shown with the assembly 178, a load side L-shaped conductor 180, a line side conductor 182 having a terminal 184 for a load end conductor 185 of the circuit breaker frame 28 of Figure 21. The current transformer 154 of the assembly 178 has an opening (not shown) through which a copper cylindrical center conductor 186 passes. In turn, the ends of the center conductor 186 are electrically connected (*e.g.*, through a peening operation) with the load side conductor 180 and the line side conductor 182. Disposed from the current transformer 154 are a set of wires 188 and a connector 190 therefor. The connector 190 mates with the corresponding connector 148 of the PCB 130 of the trip circuit 126. Each of the CTs 150,152 of the respective CT assemblies 174,176 is disposed about a corresponding one of the conductors 186 and includes a corresponding set of the wires 188. The CT assembly 174 includes a connector 194, which defines an output and which is connected to the connector 144 of the PCB 130 of the trip circuit 126. Similarly, the CT assembly 176 includes a connector 195, which defines an output and which is connected to the connector 146 of the PCB 130 of the trip circuit

126. The connectors 144,146,148 of the trip circuit 126 define three inputs, which are electrically connected to the outputs of the CTs 150,152,154, respectively. In turn, the trip circuit connector 132 defines an output having a trip signal 202, which is output through the connector 162 and the wires 160 to the trip actuator 122. Hence, there are three CT assemblies 174,176,178 for three phases. The PCB 130 receives three input signals 196,198,200 from the three CTs 150,152,154, respectively, and the PCB 128 outputs a control or trip signal 202 through the connectors 132,162 and the wires 160 to the trip actuator 122.

Figure 10 shows the assembly from Figure 9 including the base 6, the trip circuit 126, the latching mechanism 168 having the trip actuator 122, the CT assemblies 174,176,178 and the cover 8 having the earth leakage button 40 and a spring 204 therefor. As shown in hidden line drawing, the cover includes four posts 206,208 and 210,212, which correspond to the four pivot points 86,88 (as best shown in Figure 5) and 112,114 (as best shown in Figure 6), respectively, of the base 6. These posts and pivot points cooperate to pivotally capture the ends of the pivot members 78,108. The PCB 130 includes an opening 214 for the pivot point 86 and a cutout 216 for the pivot point 88.

When the earth leakage button 40 is depressed within the opening 38 by a ground fault (*e.g.*, equipment protection) bolt on unit (not shown), the plunger 97 engages the tab 96 of the trip bar 76 (Figure 5), in order to rotate such trip bar and release the rotary plunger 32 (Figure 5) to the tripped position (Figure 20), in the manner as was discussed above. The spring 204, which rests between an internal surface (not shown) of the cover 8 and a surface 218 of the button 40, biases the button plunger 97 away from the trip bar tab 76. The button 40 includes two opposing feet 220 of two legs 221 (only one foot 220 and one leg 221 are shown in Figure 10). The feet 220 extend in opposite directions (left and right with respect to Figure 10) and protrude through and are captured by the cover opening 38.

As can be seen from Figure 10, the trip unit 2 of Figures 1 and 2 integrates the flux shunt trip actuator 122, the rotary trip lever 101, the trip bar 76 (Figure 5), the electronic trip circuit 126 and the current transformer assemblies 174,176,178 into the molded case trip unit housing 4 for the molded case circuit

breaker 179 of Figure 21. It is believed that the number and complexity of parts is less than in known prior art trip units. The mechanical trip bar 76 interfaces directly with the rotary trip lever 101 and rotary plunger 32, thereby providing a very compact tripping system that provides a reliable and repeatable tripping force through such rotary plunger. In summary, the miniaturized combination of the flux shunt trip actuator 122, the rotary trip lever 101, the trip bar 76 and the rotary plunger 32 in combination with the trip circuit 126 allow the trip unit 2 to be relatively very compact, yet have relatively high reliability and relatively low cost.

Referring to Figures 11-14, the trip actuator 122 includes a bobbin assembly 231 having the wires 160 and the connector 162, a disk spacer 232, a disc magnet 233, which is preferably magnetized after the assembly steps of Figures 12-14, a housing 234, a cover 235, a wave washer 236, an upper bushing 237, an armature or plunger 238, a lower bushing 239, an internal retaining ring 240, a spring 241 and a set screw 242.

As shown in Figure 12, the disk spacer 232 is inserted into a recess 244 of the bobbin assembly 231 followed by the non-magnetized magnet 233, which is preferably magnetized after the assembly steps of Figures 12-14, in order to provide a more uniform and consistent magnetic field strength, to provide more predictable tripping without subsequent manufacturing adjustment, and to facilitate the convenient assembly of the non-magnetized magnet 233. For example, a suitable magnetizer (not shown), such as a Model 7500/900 - 6i marketed by Magnetic Instruments of Indianapolis, Indiana, may be employed to magnetize the non-magnetized magnet 233 within the assembly of the final trip actuator 122 (as shown in Figure 8). The bobbin assembly 231, the spacer 232, the magnet 233 and the housing 234 form the sub-assembly 246 of Figure 14.

Figure 13 shows the assembly of the cover 235, the wave washer 236, the upper bushing 237, the armature or plunger 238 and the lower bushing 239. This forms the sub-assembly 248 of Figure 14.

Figure 14 shows the assembly of the sub-assemblies 246,248 along with the internal retaining ring 240, the spring 241 and the set screw 242. First, the sub-assembly 248 is inserted into the recess 250 of the sub-assembly 246. Then, the

internal retaining ring 240 is employed to hold the sub-assembly 248 within the sub-assembly recess 250 by engaging the rim 251 of the sub-assembly 246. The spring 241 passes through the sub-assembly 248 and extends from the disk spacer 232 (Figure 12) to the set screw 242, which threadably engages the end 252 (Figures 13 and 14) of the plunger 238.

When the bobbin assembly 231 is energized through the wires 160 by the PCB 128 of Figure 9 in response to a detected trip condition, the resulting repelling magnetic force on the armature 238 sufficiently overcomes the attracting magnetic force of the magnetized magnet 233, in order that the spring 241 biases the set screw 242 and, thus, the plunger 238 away from the trip actuator housing 234 (to the position of the plunger 120 shown in phantom line drawing in Figure 8). In turn, the plunger 120 engages the rotary trip lever surface 116 (Figure 6). Then, the rotary trip lever surface 106 engages the tab 100 of the trip bar 76, which rotates and releases the rotary plunger 32, which trips open the circuit breaker frame 28 of Figure 21. With the plunger 238 extended, the bias of the spring 241 is sufficient to overcome the reduced attracting magnetic force of the magnet 233 on the armature 238, which is now sufficiently separated therefrom. However, in response to the reset operation (as shown in Figures 19A-19B), whenever the rotary trip lever 101 (Figure 6) moves the trip actuator plunger 238 sufficiently close to the magnet 233, the increased attracting magnetic force of such magnet, which is now sufficiently close to the armature 238, is sufficient to overcome the bias of the spring 241, thereby magnetically holding the plunger 238 within the housing 234. Otherwise, when the bobbin assembly 231 is not energized, but has been reset by the rotary plunger 32 and the rotary trip lever 101, the magnet 233 holds the armature 238 in the non-actuated, non-extended state (as shown by the plunger 120 in Figure 8).

A member, the rotary trip lever 101 (Figure 6), includes a first or on position corresponding to the on position (Figure 18) of the rotary plunger 32, a second or tripped position (Figure 20), and a third or reset position (Figures 19A-19B), which resets the trip actuator 122. In the first position, the surface 106 is offset from the trip bar tab 100. In the second position, the plunger 120 engages the surface 116 and the surface 106 engages the tab 100, in order to rotate the trip bar 76. In the

third position, the rotary plunger surface 125 engages the surface 118 and the surface 116 engages the plunger 120, in order to reset the trip actuator 122.

Similarly, a member, such as the linear plunger 120 of Figure 8 includes a first or non-actuated position (Figure 8) corresponding to the on position (Figure 18) of the rotary plunger 32, a second or actuated position (as shown in phantom line drawing in Figure 8), and a third or reset position (between the actuated and non-actuated positions), which resets the trip actuator 122 as the armature 238 is attracted by the magnet 233. The plunger actuated position engages the surface 116 and rotates the rotary trip lever 101 in response to the output control or trip signal 202 of the trip circuit 126, in order to engage the trip bar 76 with the surface 106 (Figure 6) and release the rotary plunger 32 from the on position (Figure 18). Following the trip position (Figure 20) and during a reset operation (Figures 19A-19B), the rotary plunger surface 125 engages the trip lever surface 118 (Figure 6) at about the reset position of the rotary plunger 32 and rotates the rotary trip lever 101, in order to engage the trip lever surface 116 with the trip actuator plunger 120 and move that member to the reset position thereof. As was discussed above, the rotary trip lever elastic arm 121 flexes after the trip actuator plunger 120 reaches or passes the reset position thereof, in order to accommodate any overtravel of the rotary plunger 32 beyond its reset position (Figures 19A-19B).

Referring to Figures 15 and 22, the external surface 172 of the rotary plunger 32 is pivoted outside of the housing 4 (Figure 2) through the opening 30 thereof in the tripped position (Figure 20). The surface 172 is adapted to engage a latch mechanism 253 of the circuit breaker frame 28 of Figure 21. In this example, as shown by the rotary plunger portion 74 as defined by the phantom line in Figure 22, the portion 74 is generally pie-slice shaped, with a first sub-portion 254 having a first radius and a second sub-portion 256 having a smaller second radius. The smaller second sub-portion 256 is adapted to provide clearance from other components of the circuit breaker frame 28.

During operation and, in particular, tripping operation of the circuit breaker frame 28 of Figure 21, the trip unit housing opening 30 may include debris (not shown) from such circuit breaker frame. Then, when the rotary plunger portion

74 is pivoted outside of the trip unit housing 4, the rotary plunger 32 advantageously sweeps the debris out of the opening 30.

Figure 18 (latched or on position), Figures 19A-19B (reset or overtravel position) and Figure 20 (tripped position), show the three operating positions of the rotary plunger 32 with respect to the trip actuator 122, the rotary trip lever 101 (as shown in Figure 19B), the trip bar 76 and the spring mechanism 54. As shown in Figure 18, the trip bar latch surface 102 engages and holds the rotary plunger latch surface 104, in order to latch the rotary plunger 32 in the on position thereof. This on position, in which the rotary plunger surface 172 is preferably flush with, about flush with or substantially flush to the housing surface 26 (Figure 2), is intermediate the external tripped position of Figure 20 and the internal reset position of Figures 19A-19B.

In the tripped position of Figure 20, the rotary plunger 32 trips the circuit breaker 179 of Figure 21 by rotating the latch 332 (clockwise with respect to Figure 21) as the rotary plunger 32 rotates (clockwise with respect to Figures 18 and 20) from the latched position of Figure 18 to the tripped position of Figure 20. In response to rotation (clockwise with respect to Figures 18 and 20) of the trip bar 76 against the bias of its spring 82 (Figure 5) resulting from the earth leakage button 40 (Figure 10), the attachment button 36 (Figure 3) or the rotary trip lever 101 (Figure 6), this rotation releases the trip bar latch surface 102 from the rotary plunger latch surface 104. In turn, the rotary plunger 32 rotates outward as shown in Figure 20, with its surface 172 being pivoted external to the housing 4 of Figure 2, in order to trip open the circuit breaker 179.

As shown in Figures 20 and 22, the rotary plunger 32 includes a cam surface 258, which engages a surface 260 (extending downward in Figure 5) near the latching surface 102 of the trip bar 76 (Figure 5). As the rotary plunger 32 rotates toward the reset position (Figures 19A-19B), the trip bar tab 262, which forms the surfaces 102,260, engages the rotary plunger cam surface 258. Then, at about the reset position (Figures 19A-19B), the cam surface 258 releases the tab 262 and the trip bar 76 rotates (counterclockwise with respect to the bottom left of Figure 5) under the bias of the spring 82. Hence, the trip bar latching surface 102 rotates toward the

left of Figures 18 and 20 in preparation to engage the rotary plunger latching surface 104 in the on position of Figure 18.

In the reset position of Figures 19A-19B, the rotary plunger 32 resets both: (1) the trip bar 76; and (2) the solenoid trip actuator device 122 through the rotary trip lever 101. When the operating mechanism 167 of the attached circuit breaker frame 28 of Figure 21 is reset, the rotary plunger 32 is driven by the latch 332 to the internal, non-extended reset position (Figures 19A-19B). A single motion of the rotary plunger 32 (Figures 19A-19B) is used to: (a) reset the trip actuator 122 through the rotary trip lever 101, and (b) reset the trip mechanism components (*e.g.*, the trip bar 76, since the rotary trip lever 101 is reset). The trip bar latch surface 102 re-engages the rotary plunger latch surface 104 as the rotary plunger 32 rotates from the external tripped position (Figure 20) to the internal reset position (Figures 19A-19B) thereof. As the rotary plunger 32 pivots from the external tripped position to the internal reset position thereof, the rotary plunger surface 125 rotates the trip lever 101 (as shown in Figure 19B), in order to reset the trip actuator 122 through its plunger 120 (Figure 8). Any overtravel of the rotary plunger 32 flexes the rotary trip lever elastic arm 121.

After a trip, the trip actuator 122 is no longer energized; however, the trip actuator spring 241 (Figures 11 and 14) causes the solenoid armature or plunger 238 to remain extended, thereby preventing the trip bar 76 from returning to the latched or on position (Figure 18) under the bias of its spring 82 (Figure 5). For a reset operation (Figures 19A-19B), the rotary plunger 32 rotates the rotary trip lever 101, through its resilient arm 121, in order to cause the trip actuator 122 to be reset to the position where the armature or plunger 238 is held in place by the magnet 233 thereof. At the same time, the trip bar spring 82 causes the trip bar 76 to rotate (counterclockwise with respect to Figures 19A-19B) back to its latching position (Figure 18), in order to hold the rotary plunger 32 in the latched or on position of Figure 18.

Figure 21 shows the molded case circuit breaker 179 including the circuit breaker frame 28 and the removable trip unit 2 of Figure 1. Examples of circuit breakers and circuit breaker frames are disclosed in U.S. Patent Nos.

5,910,760; 6,137,386; and 6,144,271, which are incorporated by reference herein. The example breaker or interrupter 179 includes a main base 300 and primary cover 302 attached to a secondary cover 304. The base 300 and covers 302,304 form a housing 305. A handle 306 extends through a secondary escutcheon 308 in the secondary cover 304 and an aligned primary escutcheon 310 in the primary cover 302. The operating mechanism 167 is interconnected with the handle 306 and assists in opening and closing separable main contacts 312 as is well known. The circuit breaker 179 has a line end 314 including a plurality of line terminals 315,316,317, a load end 316 including a plurality of load terminals 318,319,320, a right side accessory region or pocket 322 and a left side accessory pocket or region 324. The separable contacts 312 are electrically connected between the line terminals 315,316,317 and a plurality of load end terminals 325,326,327.

The load end terminals 325,326,327 of the circuit breaker frame 28 are electrically connected to the line end terminals 14,16,18 (as best shown in Figures 1 and 2) of the trip unit 2 by a plurality of conductors 328,329,330, respectively. In turn, the corresponding load end terminals 20,22,24 (Figure 1) of the trip unit 2 are electrically connected the corresponding line end terminals 14,16,18, respectively, by the conductors 186 (Figure 9). Those load end terminals 20,22,24 are also electrically connected by suitable user installed terminations (not shown) to the load terminals 318,319,320, respectively, of the circuit breaker frame 28.

The latch mechanism 253 latches the operating mechanism 167 to provide the closed position of the separable contacts 312 and releases such operating mechanism to provide the open position of such separable contacts. The latch mechanism 253 includes a primary frame latch (not shown), which operates or rotates on a primary frame latch pivot (not shown). The primary frame latch cooperates with the secondary frame latch 332, which rotates on a secondary frame latch pivot 334. Actuation of the latch mechanism 253 occurs exclusively by way of the utilization of the resetable trip unit rotary plunger 32 (Figures 4, 15 and 22), which is normally contained entirely within the removable trip unit 2. In particular, the pivotable secondary frame latch 332 is in disposition to be pivoted by the rotary plunger surface 172 through the rotation of rotary plunger 32.

When the trip unit 2 is disengaged (not shown) from the circuit breaker frame 28, a surface 336 thereof cams the rotary plunger surface 172 (Figure 20) to pivot the rotary plunger 32 (counter-clockwise with respect to Figure 20) to be about flush with the trip unit housing surface 26.

In the tripped position of the rotary plunger 32, its rotating action (clockwise with respect to Figure 20) sweeps debris out of the way in the opening 30 of the trip unit 2. Also, the rotary plunger 32 moves out of the way (counter-clockwise with respect to Figures 18 and 20) for ease of removal of the trip unit 2 from the circuit breaker frame 28, even in the tripped position thereof.

The rotary plunger design provides more travel in order to reliably trip open the circuit breaker frame 28. After being tripped, when the trip unit 2 is removed from the circuit breaker frame 28, the frame surface 336 engages the rotary plunger 32 and rotates it toward the on position, thereby permitting removal of the trip unit 2 from the frame 28.

The user may push in and latch the rotary plunger 32 in the on position thereof prior to insertion of the trip unit 2 in the circuit breaker frame 28.

Although not required, the rotary plunger 32 may have two levels 254,256 (Figure 22) in order to provide clearances with the circuit breaker frame components.

The rotary plunger 32 sweeps debris by rotating and, thus, by providing a sweeping action.

The surface 125 of the rotary plunger 32 engages the elastic arm 121 of the rotary trip lever 101. The rotary trip lever 101 advantageously compensates for excess reset travel of the rotary plunger 32 as driven by the circuit breaker frame 28 of Figure 21 during a reset operation. This design optimizes component geometry, thereby lowering part and labor costs.

While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be

illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the claims appended and any and all equivalents thereof.